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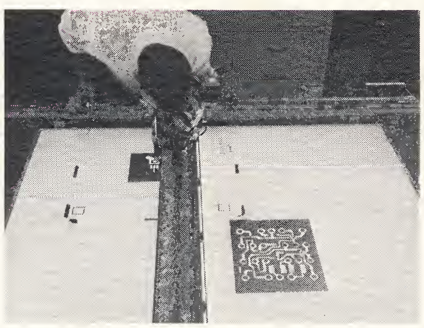

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HAND-CUT MASKING FILM FOR THE GRAPHIC ARTS

the
knife-cut
light-safe
masking film
laminated
to a stable
polyester base

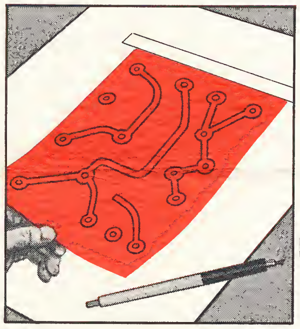
by

Ulano T.M.

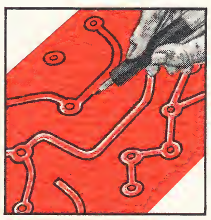
DETAILS, SPECIFICATIONS AND TEST KIT OFFER

HERE'S HOW...

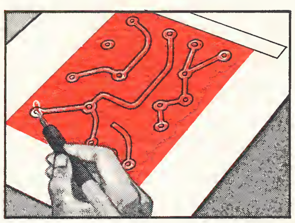
THE ELECTRONIC INDUSTRY IS USING THESE FAMOUS ULANO FILMS IN ULTRAMINIATURE MASK TECHNOLOGY AND COMPLEX PRINTED CIRCUITRY



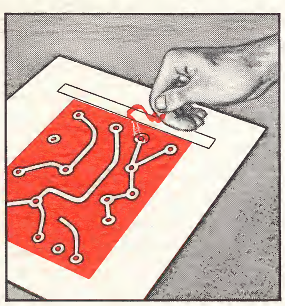
Cut a piece of the desired film large enough to cover area to be masked. Tape it down firmly at the top *with dull-side up.*



With sharp blade, outline the areas to be masked. *Do not cut through the backing sheet.* The Ulano Swivel Knife does the job quickly, easily.



Using the tip of the blade, lift up a corner of the film thus separating it from the backing sheet.



Now carefully peel off the film as outlined leaving a completed mask, positive or negative, that corresponds exactly to the desired pattern.

"Ulano"-"Rubylith"-"Amberlith" are registered trade marks of the Ulano Companies.

Ulano T.M.

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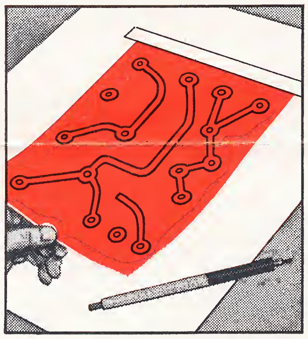

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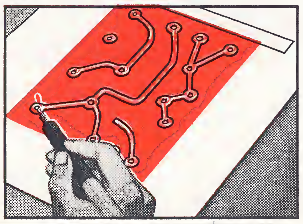

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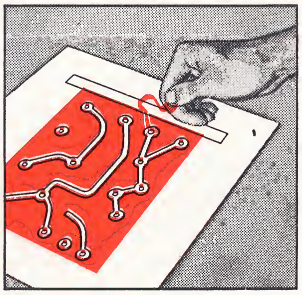

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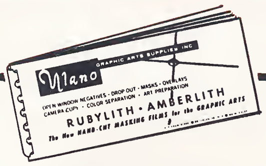

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Reprinted from REPRODUCTION METHODS, January 1966 issue

MAKING MASKS for electronic components

Fig. 1 On the left is the IBM SLT microelectronic circuit module. The uncoated module showing the circuit pattern is on the right. In the center can be seen the transistors and diodes which are silicon chips .028 (28/1,000) inches square.

The technicians at IBM's East Fishkill Facility in Hopewell Junction, N.Y. seem to take mask making for electronic components in stride. We, as laymen, found the operation slightly fantastic.

A little publicized aspect of electronic component fabrication is mask technology. Mask technology, however, by no means takes second place to the areas of crystal growth, diffusion or evaporation.

Mask technology relates to the engineering and development of stencil-like masks used in the processing of semiconductor devices (silicon transistors and diodes) and circuits (*Fig. 1*). The masks are of two types: a glass plate containing an emulsion-formed design which passes or blocks out light in much the same fashion as an ordinary photograph negative; and a metal plate with etched apertures that control the deposition of evaporated metals or conductive pastes.

Solid Logic Technology (SLT) devices and circuits for IBM System/360 are particularly dependent on mask technology. This dependence becomes apparent when one considers the process steps required for both the SLT devices and the circuits that contain the devices. Specifically, the intent of processing by mask technology is to form an array of devices or circuits, with each of their parts being properly isolated and interconnected so that a given design can be duplicated exactly.

Making the device

The SLT devices are "chips" of silicon .028 in. square. More than 1,000 are formed simultaneously on a half-dollar size water of single-crystal silicon. The finished devices are

made as either transistors or diodes.

The parts of the transistor (base, emitter and collector) appear as a pattern of geometrical areas across the surface of the wafer. They are formed in a series of like processes each of which is made up of photolithography, etching and diffusion steps. Photolithography refers to the use of a glass mask of a particular pattern for exposing a photosensitive coating on the silicon wafer. Etching selectively removes portions of the wafer surface which were blocked out by the opaque areas on the glass mask. The etched-out portions receive impurities for altering their electrical characteristics, thereby becoming the base, emitter and collector regions. The manner by which the impurities are introduced is known as diffusion. Therefore, in general, these regions are called diffused regions.

Metal is then evaporated onto the entire wafer surface and selectively etched through means of another exposure-through-a glass mask-process. The result is an array of conductors emanating from each of the diffused regions.

A thin layer of protective glass is then applied to the wafer surface. This glass, .000060 in. (60 millionths) thick replaces metal cans that have classically been used for protecting semiconductor devices. A photolithographic step is again employed, with the aid of another glass mask, to etch holes into the glass leading to the terminals of the evaporated conductors.

At this point a series of metallic evaporations, including solder evaporation, are conducted through a metal mask having holes in perfect registration with the holes etched in the glass. Then, using another metal mask as an overlay, metal granule-like balls (.005 in. in diameter) are dropped into the holes and fused to the solder deposits. The fabrication process is completed after cutting, which slices the wafer into individual device chips.

Making the circuit

The SLT circuits are ½ in. square ceramic pieces with conductors and resistors applied by a screen printing process in two separate steps. Screen printing entails spreading special

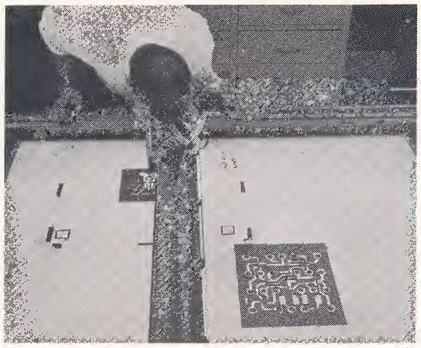

Fig. 2 A scriber cuts a piece of artwork on special laminated plastic.

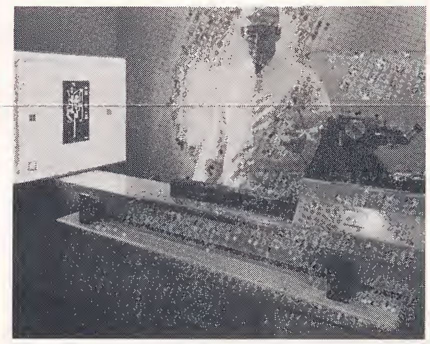

Fig. 3 Artwork 200X size is photographically reduced to 20X size.

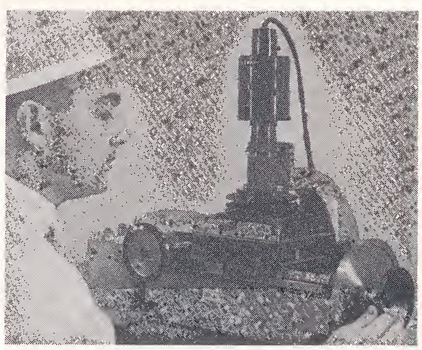

Fig. 4 The 20X art is reduced to normal size with photorepeater camera.

Fig. 5 In one step, fly's eye camera reduces 500X image producing series of actual size images on glass plate.

inks across a mask containing the pattern to be transferred onto the ceramic surface. The conductor pattern, screened first, is an array of narrow lines. The resistor pattern, screened second, is a pattern of rectangular blocks, later trimmed to exact electrical resistance valves. Copper pins extend through the ceramic (or module) to serve as connectors to further levels of assembly. Semiconductor devices are attached at pre-established locations to the networks formed by the screen printed conductors and resistors. The entire assembly is finally protected by a metal cover.

Making the masks

The mask-making process begins with a piece of artwork that has been cut or scribed on a transparent plastic laminated to a red, photographically opaque, film. During scribing, the red layer is peeled off leaving a transparent pattern that corresponds to that of the desired device (*Fig. 2*).

In general, a separate piece of artwork is required for each of the regions of the semiconductor device, and for each of the steps necessary to construct interconnections and contacts. Artwork is often the most costly and time-consuming part of the complete process. This is the first step in translating the engineer's design into a practical layout for the operating device, and the specifications dictated by the designer must not only be within the bounds of electrical theory but also within the tolerances associated with the state-of-the-mask art.

For fabricating the SLT device, which is 28 mils (or thousandths-of-an-inch) square, the glass mask patterns require typical tolerances of ±.000020 in. (20 millionths). The tolerances become more critical, of course, when multiple circuits are to be made in a chip of silicon from 50 to 100 mils square.

For the SLT transistor, a typical base-region size is 6 x 4 mils. Attempts to cut areas in initial artwork at this size would be futile. Therefore the artwork is cut either 200 or 500 times larger than final size, resulting in artwork sizes (for the entire device) of six inches or 15 inches square.

(continued on next page)

MAKING MASKS *(continued)*

These sizes are convenient for the cameras used in the subsequent reductions. For lines which may be only .0001 in. wide, the artwork would be cut up to 1,500 times normal size.

Following inspection and a quality check of the artwork, it is sent to the photographic laboratory, a controlled environment room, for photographic reduction and transfer to a glass plate. For the semiconductor device glass masks, two methods of photographic reduction are used.

In the first method, the 200X size artwork is photographically reduced to a 20X size (*Fig. 3*). Then, by a step-and-repeat method, this 20X size single-image art is repeatedly photographed onto an emulsion glass plate to form an array of identical images, which are the desired final size, across the glass (*Fig. 4*). This actual-size glass master can then be used as a master for contact printing production glass masks.

The other reduction method produces a multitude of images of the 500X size artwork simultaneously onto an emulsion glass plate, reduced to final size in one step. This is made possible through means of a "fly's eye" lens system, so-called because the lens is in actuality an array of minute lenses, much like the sight organ of the fly (*Fig. 5*).

The manufacture of glass masks requires mastery of artwork and photography techniques. Microscopes are required to see the image pattern clearly and with definition. In addition, a set of device masks, each of a different pattern but all representing a single device structure, must register to within millionths of an inch (*Figs. 6a, 6b*).

Completed glass masks are inspected for sharpness, density, configuration, alignment, squareness, parallelism, resolution and cleanliness. Also, mask-to-mask registration is critically examined.

Glass masks can be used only a limited number of times either as masters from which contact prints are made, or as production masks for device manufacture. This is due to imperfections caused by handling and wafer-to-mask contact. In addition, the emulsion surface is difficult to keep clean.

Metal masks are required where the circuit patterns to be formed require the transference of material rather than only the photographic latent images. They are used to fabricate the device interconnections and contacts and the circuit patterns on the module (*Fig. 7*).

Molybdenum is the most common metal used, because of its compatibility with the temperatures used in the various device and circuit steps. Sheets of molybdenum are thoroughly cleaned with suitable degreasing agents and prepared for the etching steps to follow by coating both sides with a photoresist. (These sheets may range in thickness from 1 to 10 mils depending on the mask being made.) A sheet is then mounted in a fixture that permits placement of the proper glass masks over both surfaces. Both surfaces are exposed to light through the glass masks simultaneously. The photoresist is then developed and the pattern is etched in the molybdenum.

Etching is a critical step and, therefore, precisely monitored. The etch rate differs for each mask pattern being made and is dependent on material thickness and the area to be etched. The etch solution is chemically monitored and controlled for process compatibility with pattern dimensions.

After etching, the masks are examined on a comparator screen to check area dimensions, registration and pattern fidelity. Depth of etching is also checked. Depth of etching can be held to tolerances of ± 10 microns. Typical tolerances for the depth of etching are between 40 and 50 microns. (One micron is one-millionth of a meter.)

Following final cleaning, inspection and quality control steps, the masks are ready for use on the device or circuit production line. □

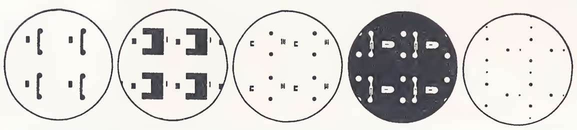

Fig. 6a Typical set of glass masks is shown top left.
Fig. 6b Magnified views of portions of the glass masks are seen bottom left. These masks represent different parts of silicone device and must register perfectly with one another.

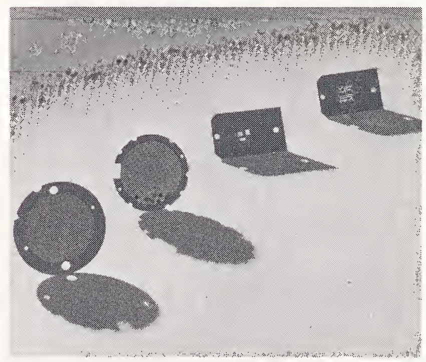

Fig. 7 Complete set of metal masks comprises two for completion of silicone devices (L.); two for screen printing patterns on SLT ceramic module (R.).

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#25 Fotomask	.0026	.0025	.0023
RA5	.0045	.0043	.0041
5DR	.005	.0048	.0046
75DR	.0063	—	—
Ulano Amberlith T.M.			
A3A	.0038	.0037	.0035
3DA	.0043	.0042	.004
#27	.0026	.0025	.0023
5DA	.005	.0048	.0046

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